A Key to the Tadpoles of North Carolina

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ABSTRACT.— A dichotomous key for identifying the tadpoles of North Carolina and a guide for their field identification with a hand lens are offered. Problems in identifying tadpoles are discussed. The key should be useful throughout the southeastern United States, because it treats most of the species present in this area.

INTRODUCTION

Although anuran larvae are excellent subjects for various types of field and laboratory research, the difficulty of correctly identifying tadpoles is well known. Early keys were either difficult to use (e.g., Wright and Wright 1949) or restricted in taxonomic (e.g., Orton 1952) or geographic (e.g., Smith 1934) coverage. Altig (1970) provided a key to all of the tadpoles found in the continental United States and Canada, and proposed a standard terminology for use in identifying tadpoles. Later references to Altig will be to this 1970 paper. A complete key to variable animals such as anuran larvae can prove difficult to use. Geographic variation can produce ambiguities in identification, and characters that may be diagnostical at a local level may prove impossible to integrate into a more thorough treatment.

North Carolina, with 30 species of anurans (Martof et al. 1980), provides an excellent situation for the development of a more restricted key. The extensive phenotypic variability seen in some species, such as *Hyla crucifer* and *Rana clamitans*, often precludes the effective use of Altig's key in the state. A North Carolina key should also be useful in the southeastern United States, because it includes most of the species found in this area.

My local key was constructed from Altig's and others in the literature, specimens collected by me and others during my four years in North Carolina, and laboratory rearings of unidentified tadpoles. Some key characters used by other workers subsequently proved unreliable and have been deleted. I examined many specimens of 27 of the 30 North Carolina species, including living individuals. *Pseudacris brimleyi, P. brachyphona*, and *Rana heckscheri* were not personally examined. *Hyla versicolor* was obtained from Giles County, Virginia, and specific identity was verified by karyotype analysis. The occurrence of *H. versicolor* in North Carolina remains problematic (Martof et al. 1980).

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USE OF THE KEY

This contribution should prove useful for live or preserved animals in development stages 25 through 40 (Gosner 1960). The key is not arranged phylogenetically. General arrangement and terminology follow Altig's.

Altig discussed some of the major sources of difficulty in tadpole identification, beginning with the problem of poor preservation. Coloration, useful in identifying live material, will fade in preserved specimens. Labial teeth can fall out, and keratinized skin layers can be dislodged from their underlying structures.

Larval anurans are highly susceptible to environmental influences on morphology. For example, food type can affect mouthpart morphology, causing some distortions of the normal appearance, as is evident in a comparison of laboratory-reared and field-collected tadpoles. Ambient temperatures will affect development rates, and may influence allometric growth patterns (see below). The tails of many tadpoles are damaged by predators, particularly nymphal dragonflies (Caldwell et al. 1980). This may affect comparisons based on length ratios, either because of the tail's abbreviated length or because of a change in its overall shape as regeneration occurs. In addition, a regenerated tail often has a blackened tip or large blotches or large blotches on the fin, marks that may not be part of the normal pattern. Color of a live animal can vary with background. *Rana clamitans* larvae developing in a pond that contains a high level of gray clay in suspension (as in some ponds in the Sandhills region) will be very pale, while larvae in other situations may range from green to dark brown.

Many characters vary ontogenetically. The most obvious of these is color. The clear belly of young *Rana clamitans* larvae will become an opaque, cream color as the animals develop. The number of rows of labial teeth and the length of the rows change with tadpole age and size. The most subtle ontogenetic variations are the allometric shape changes exhibited by some species. The notable flagellum of a *Hyla femoralis* tadpole is not present in a young larva, but becomes increasingly well developed as the tadpole grows. Many species with broad fins, like *Hyla gratiosa* and *H. chrysoscelis,* have more streamlined profiles as small larvae. All these sources of phenotypic variation should be kept in mind when using any key to tadpoles.

KEY TO THE TADPOLES OF NORTH CAROLINA

1. Jaws without keratinized sheaths; oral disc and labial teeth absent (Microhylidae) ..... *Gastrophryne carolinensis*
   Jaws with keratinized sheaths; oral disc and labial teeth present (Fig. 2) 2
2. Anus medial (Fig. 4A) 3
   Anus dextral (Fig. 4B) 4
3. Oral disc emarginate (Fig. 2); tooth row formula 1-2/3; spiracle distinctly on left side of body (Fig. 3A) (Bufonidae) 5
   Oral disc not emarginate (Fig. 2); tooth row formula 2/4 or more; spiracle ventrolateral (Pelobatidae) ..... *Scaphiopus holbrooki*
4. Oral disc emarginate (Ranidae) 33
   Oral disc not emarginate (Hylidae) 8
5. P-2 (see Fig. 2) with distinct median gap; P-3 less than 0.50 P-1; papillary border extends to lateral tips of P-2; light color in life ..... *Bufo quercicus*
   P-1 with no median gap; P-3 greater than 0.50 P-1; papillary border extends *distinctly* around P-2; dark color in life 6
6. Substantial submarginal papillae (Fig. 2), particularly around emarginate areas of oral disc; dorsal tail fin height equal to musculature height (Fig. 1); dorsal fin may be higher than ventral fin ..... *Bufo terrestris*
   Few if any submarginal papillae; dorsal tail fin height lower than musculature height; fins subequal in height 7
7. Dorsum unicolored; snout sloping in lateral view; tail musculature distinctly bicolored; tail fin height/musculature height 2.0 or less ..... *Bufo americanus*
   Dorsum often slightly mottled in life; snout rounded in lateral view; tail musculature often not distinctly bicolored; tail fin height/musculature height greater than 2.0 ..... *Bufo woodhousei fowleri*
8. Two rows of posterior labial teeth (Fig. 2) 9
   Three or more rows of posterial labial teeth 13
9. A-2 gap (Fig. 2) wide; spiracular tube at least partly free from body wall; body slightly depressed; tail tip often solid black *(Acris)* 10
   A-2 gap narrow to moderate; spiracular tube fully attached to body wall; body globular; tail tip, if black, with mottle or blotched black edges 11
10. Free section of spiracular tube long, almost entire length of tube; throat dark; tail musculature finely flecked; Coastal Plain ..... *Acris gryllus*
    Free section of spiracular tube short, less than or equal to half the length of tube; throat light; tail musculature mottled or reticulated; Piedmont and mountain valleys ..... *Acris crepitans*
11. Tail musculature distinctly striped in lateral view; light stripe extends from dorsal tail musculature stripe to eye; throat and chest may be mottled; dorsum of tail musculature often banded or with saddles ..... *Limnaoedus ocularis* (part)
    Tail musculature not or only faintly striped, but without extension to eye; throat and chest light; dorsum of tail musculature not banded 12

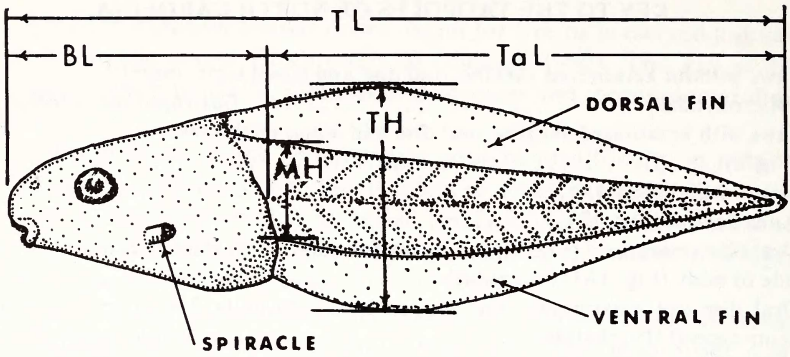

Fig. 1. Left lateral aspect of a tadpole. TL = total length; BL = body length; TaL = tail length; MH = musculature height; TH = tail height. Redrafted from Altig (1970).

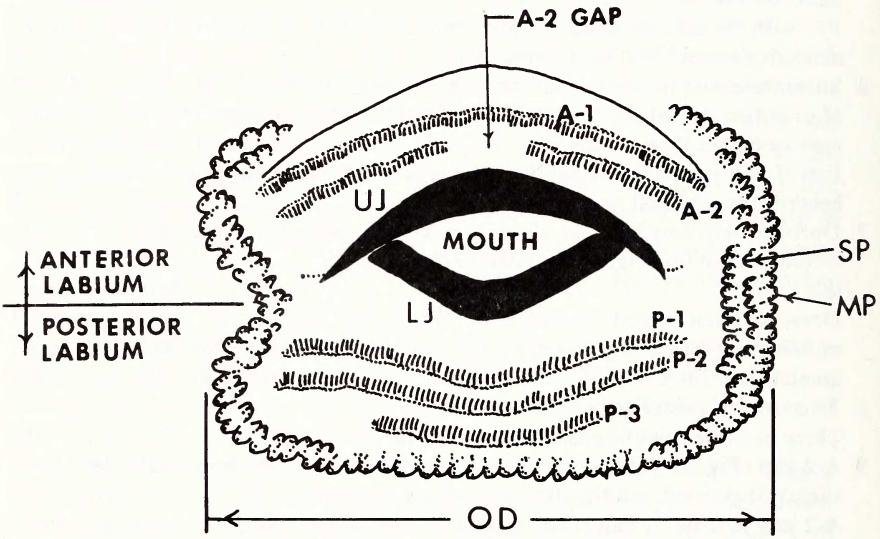

Fig. 2. Tadpole mouth parts, schematic. UJ = upper jaw (mandible); LJ = lower jaw (mandible); A-1,2 = first and second anterior tooth rows; P-1,2,3 = first, second and third posterior tooth rows; SP = submarginal papilla; MP = marginal papilla; OD = oral disc (shown emarginate on viewer's left, marginate on right). Redrafted from Altig (1970).

12. Tail musculature unicolored or bicolored; fins clear or with stellate melanophores; small black dots often present on body; A-2 subequal to A-1; one row of marginal papillae (see Fig. 2); snout round when viewed dorsally ..... *Pseudacris triseriata* (part)
Tail musculature mottled; fins clear or with large blotches; no dots on body; A-2 longer than A-1; two rows of marginal papillae; snout square when viewed dorsally ..... *Hyla crucifer* (part)

13. Posterior gap in papillary border 14
    No posterior gap in papillary border 16
14. Tail musculature distinctly striped and stripe may extend forward to eye; snout rounded or pointed in dorsal view 15
    Tail musculature mottled or indistinctly striped, but in no case does a light stripe extend forward to eye; snout square in dorsal view ..... *Hyla crucifer* (part)
15. Tail musculature stripe extends to eye; snout round when viewed dorsally; posterior gap in papillary border greater than or equal to length of P-3; interocular distance wide, only slightly less than maximal head width ..... *Limnaoedus ocularis* (part)
    No extension of tail musculature stripe to eye; snout tapered or slightly pointed in dorsal view; posterior gap in papillary border less than length of P-3; interocular distance narrow, substantially less than maximal head width ..... *Hyla andersoni* (part)
16. P-3 length 0.50 or more times length of P-2; P-3 longer than upper jaw 17
    P-3 length very short, less than 0.50 times length of P-2; P-3 subequal to upper jaw 20
17. Submarginal papillae absent or few; dorsum of tail musculature usually with one black saddle slightly anterior to midlength ..... *Hyla gratiosa* (part)
    Substantial submarginal papillae; no black saddle on dorsum of tail musculature 18
18. Tail musculature distinctly striped; well developed flagellum at tip of tail; reddish color in life ..... *Hyla femoralis*
    Tail musculature not striped; flagellum absent; golden to brown or bluish color in life 19
19. Dorsal fin height equal to or greater than musculature height; throat seldom pigmented; dorsal fin never extends anterior to midway between spiracle and eye ..... *Hyla chrysoscelis, Hyla versicolor*
    Dorsal fin height less than musculature height; throat pigmented in life; dorsal fin extends to posterior border of the eye ..... *Hyla squirella*
20. Tail musculature striped 21
    Tail musculature not striped 26
21. A-2 gap wide ..... *Pseudacris brimleyi*
    A-2 gap narrow 22
22. Light dorsal stripe on tail extends to eye; fins clear or with a few stellate melanophores; dorsum of tail musculature banded or marked with saddles ..... *Limnaoedus ocularis* (part)
    Dorsal stripe does not extend to eye; fins clear or mottled; dorsum of tail musculature not banded 23
23. Tail stripe distinct; snout rounded when viewed dorsally; body slightly depressed 24
    Tail stripe may or may not be distinct; snout squarish or tapering in dorsal view; body not depressed 25
24. Dorsal fin originates anterior to spiracle ..... *Pseudacris ornata* (part)
    Dorsal fin originates posterior to spiracle ..... *Pseudacris triseriata* (part)

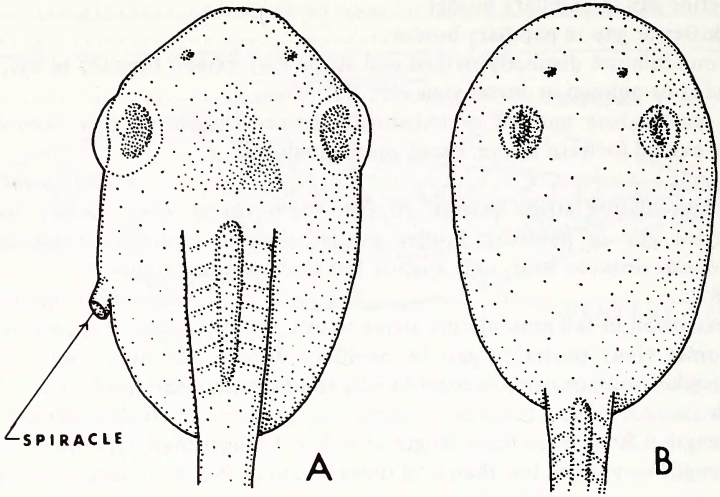

Fig. 3. Eye positions, dorsal aspect. A. Lateral eyes (and spiracle). B. Dorsal eyes. Redrafted from Altig (1970).

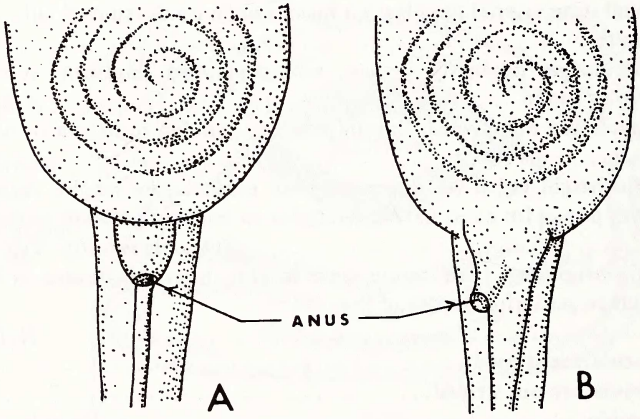

Fig. 4. Anus positions, ventral aspect. A. medial. B. dextral. Redrafted from Altig (1970).

25. Tail stripe faint; snout square when viewed dorsally; snout-spiracle distance/body length greater than 0.60; spiracle just below eye level; dorsal fin higher than ventral fin; interocular distance only slightly less than maximum head width ..... *Hyla crucifer* (part)
    Tail stripe distinct; snout tapering in dorsal view; snout-spiracle distance/body length less than 0.60; spiracle well below eye level; fins equal in height; interocular distance markedly less than maximum head width ..... *Hyla andersoni* (part)
26. Total length (Fig. 1) greater than 45 27
    Total length less than 45 mm 28

27. Jaws wide and rounded; tail musculature unicolored .... *Hyla gratiosa* (part)
Jaws narrow and angular; tail musculature bicolored ..... *Pseudacris ornata* (part)
28. Dorsal fin originates anterior to spiracle 29
Dorsal fin originates at or posterior to spiracle 31
29. Fins clear or with few stellate melanophores; fins rounded; dorsal fin higher than ventral fin 30
Fins and tail musculature mottled or reticulated; fins tapering toward the tail tip; dorsal and ventral fins equal in height ..... *Hyla cinerea*
30. Jaws wide and rounded; dorsum of tail musculature usually with black saddle slightly anterior to midlength; tail musculature unicolored ..... *Hyla gratiosa* (part)
Jaws narrow and angled; no black saddle on dorsum of tail musculature; tail musculature bicolored ..... *Pseudacris ornata* (part)
31. Fins and tail musculature mottled or reticulated; body somewhat globular; snout square when viewed dorsally ..... *Hyla crucifer* (part)
Fins and tail musculature clear or with a few stellate melanophores; body somewhat depressed; snout round when viewed dorsally 32
32. Body dark brassy in life; dorsal fin terminates far posterior to spiracle ..... *Pseudacris brachyphona*
Body color not dark brassy; dorsal fin terminates at or slightly posterior to spiracle 33
33. Dorsal fin higher than ventral fin and equal to tail musculature height ..... *Pseudacris triseriata* (part)
Fins subequal and both lower than musculature height ..... *Pseudacris nigrita*
34. Four or more rows of teeth on anterior or posterior labium ..... *Rana sylvatica* (part)
Less than four rows of teeth on both anterior and posterior labium 35
35. A-2 gap ratio greater than 1.5; dorsal fin originates at or only slightly posterior to spiracle ..... *Rana sylvatica* (part)
A-2 gap ratio variable; dorsal fin originates far posterior to spiracle 36
36. Lower jaw wide; nostrils medium to large; skin thin, gut visible, with weakly pigmented belly in larger specimens; small animals uniform in color, even when preserved ..... *Rana pipiens* group: 37
Lower jaw narrow; nostrils small; skin thick; gut usually not visible, with strongly pigmented belly in larger animals; small animals with gold transverse bands on anterior part of body, appearing unevenly pigmented when preserved ..... *Rana catesbeiana* group: 39
37. A-2 gap ratio 2 or more; P-1/P-3 length ratio 1.3 or greater... *Rana palustris*
A-2 gap ratio less than 2; P-1/P-3 length ratio less than 1.5 38
38. No keratinized areas at medial tips of P-1; A-2 gap ratio often greater than 1.0; color variable ..... *Rana sphenocephala*
Keratinized areas present at medial tips of P-1; A-2 gap ratio always less than 1.0; color usually dark ..... *Rana areolata*
39. Tail musculature unicolored or mottled, but not striped; fins clear or mottled, but not in any particular pattern 41
Tail musculature distinctly bicolored or striped; fins either striped (or with a row of dots) or marked around edges 40

40. Tail musculature distinctly bicolored; fins without stripe; larger specimens have prominent black edging around a clear or speckled fin ..... *Rana heckscheri*
    Tail musculature distinctly striped; stripe or row of dots (formed by pigment around the lateral line pores) present on dorsal fin; no black edging on tail fins ..... *Rana virgatipes*
41. A-2 gap ratio greater than 0.50; body and tail patterned with distinct black dots; belly light green, white, or yellow in life ..... *Rana catesbeiana*
    A-2 gap ratio less than 0.50; body and tail lacking distinct black dots; belly of larger individuals is cream or white in life ..... *Rana clamitans*

NOTES ON FIELD IDENTIFICATION

Many animals can be diagnosed to genus or species in the field with the use of a hand lens. Small tadpoles are always difficult to identify, but the following notes should allow larger individuals to be placed into one of five principal groups.

Hylidae: body square in dorsal view, eyes lateral; nostrils small compared to eyes; dextral anus; oral disc not emarginate; never black in color, but can range from bluish to brown.

Rana: body oval or round in dorsal view, eyes dorsal or dorsolateral; nostrils small compared to eyes; dextral anus; oral disc emarginate; color diagnostically unreliable.

Bufo: body round or oval in dorsal view, eyes dorsal and with a "cross-eyed" aspect; nostrils large, and head appears to have a "snout"; median anus; oral disc emarginate; color may be dark or light *(Bufo quercicus).*

Scaphiopus holbrooki: body round or oval in dorsal view, eyes close-set and dorsal; head wide relative to body width; entire body moves from side to side while swimming; median anus; oral disc not emarginate; color black.

Gastrophryne carolinensis: body round in dorsal view, distinctly depressed; eyes wide-set and lateral; median anus; no oral disc; color dark, although larger individuals have mottled venters and a stripe on the tail musculature.

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